Forest Ecology and Management, 33/34 (1990) 559–570
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

Inventory technology: 'Ebb tides', 'flash floods' and 'whirlpools'

H. Gyde Lund
USDA Forest Service, Timber Management Staff, P.O. Box 96090, Washington, DC 20090-6090 (U.S.A.)

ABSTRACT

Lund, H.G., 1990. Inventory technology: 'Ebb tides', 'flash floods' and 'whirlpools'. *For. Ecol. Manage.*, 33/34: 559–570.

The development and implementation of inventory techniques are cyclic. For a long while, our inventory procedures in the USDA Forest Service have been rather stable. Now, given new information requirements and an onslaught of new technology, our needs, capabilities, and methodologies are rapidly changing. This paper reviews past ('ebb tides') and emerging techniques ('flash floods'). It also lists some of the problems ('whirlpools') we will encounter in implementing the changes. While the paper addresses resource inventories within the USDA Forest Service, the potential and problems are applicable to the inventory of any ecosystem including the forested wetlands. Lastly, some thoughts for follow-up global actions are presented.

INTRODUCTION

This paper is part of a series of 'ecosystem' theme conferences that the International Union of Forestry Research Organizations (IUFRO) and the Society of American Foresters (SAF) have sponsored together in recent years. The first focused on arid lands and was held in La Paz, Mexico (Lund et al., 1981). The second dealt with the cold and high-altitude regions of the world (LaBau and Kerr, 1984). Fairbanks, Alaska was the site for this meeting. In 1987 we held a meeting in Chetumal, Mexico addressing concerns of the tropics (Lund et al., 1987). In 1989 we set up an international conference and workshop on *Global Nature Resource Monitoring and Assessments: Preparing for the 21st Century,* held 24–30 September in Venice, Italy. But now it is time to address the forested wetlands.

This paper, which focuses on some of the things that are happening in the United States Department of Agriculture (USDA) Forest Service will, it is hoped, provide an enlightening and entertaining outlook on what is currently being done in the way of resource inventories, traditions that are changing ('ebb tides'), where we are headed in the future ('flash floods'), and areas of

concern ('whirlpools') where the two forces meet. Matters for future consideration are further mentioned.

BACKGROUND

As evidence by this conference and others like it, concern about wetlands has certainly reached the international community in recent years. Wetland areas are in demand either for the functions they serve naturally, strategically (Abercrombe and Raymer, 1988), or for conversion to other uses. The fertile soils of the wetlands attracts agriculture and the flatness of the terrain lures industry and urban development.

Forested wetlands are particularly in demand. There are an estimated 19.4 million ha (48 million acres) of forested wetlands in the conterminous United States (Frayer, 1987). These lands supply valuable food and wood fiber, offer recreation opportunities, provide homes for critical wildlife and plant species; provide biological diversity, and serve as water storage, tertiary waste treatment, and purification areas. Careful planning and prudent management on some of the forested wetlands can allow intensive timber management and protect the dependent resources.

The identification and location of wetlands is very important to the decision-maker, as indicated in the previous papers. The United States Department of the Interior (USDI) Fish and Wildlife Service is responsible for the identification and mapping of these lands in the U.S.A.

But if the decision-maker is to make sound judgements regarding land use, he or she must also have knowledge of the sensitivity of the ecosystem, the wealth of resources that the forested wetlands contain and the services they can provide. Information about the resources and the sensitivity of the land to management activities come from inventories. The utility of the inventories is in turn governed by the technology in use.

The USDA Forest Service is responsible for inventorying the resources on the forested wetlands in the U.S. Inventory responsibilities within the Forest Service are divided into two areas. Lands designated as National Forests and National Grasslands are under the jurisdiction of the National Forest System (NFS). All other federal, state and private lands fall within the inventory responsibility of the Forest Service's Forest Inventory and Analysis (FIA) Research Program.

National Forest Inventories

NFS has the responsibility of inventorying and monitoring all of the renewable resources on nearly 77.3 million ha (191 million acres) of National Forests and National Grasslands. There are approximately 3.6 million ha (9 million acres) of wetlands on the National Forests and National Grasslands

including a rough estimate of 2.1 million ha in Alaska. Of the wetlands occurring on the National Forest and Grasslands, approximately 1 million ha (2.5 million acres) are classed as forested wetlands, of which roughly 280 000 ha are in Alaska (P.E. Avers, personal communication, 1988).

The Forest Service uses soil resource inventories, stand maps, and existing U.S. Fish and Wildlife Service Wetlands Inventory maps for delineating wetland ecosystems for planning purposes. If these maps are not available, the lands are mapped using remote sensing (often provided by Ducks Unlimited[1]) and ground surveys are often used. The identification of wetlands is generally done by the watershed, soils or wildlife specialists at the forest level. For project work, on-site investigations for soil, hydrology, and vegetation information are used to verify or change the maps.

The Forest Service manages its forested-wetland ecosystems for flood control, drought moderation, wildlife and plant habitat, recreation, water quality and quantity, wood fiber, archeological and cultural resources, visual resources, and tertiary waste disposal (McLaughlin, 1988). Thus we need to know more than the extent and location of the wetlands.

Inventories of the resources on these lands are currently carried out according to resource functions: thus the foresters would inventory the timber resources; the soils and watershed people the soil and water resources; the wildlife biologists the wildlife resources, etc. Techniques used and data collected vary from Region to Region and Forest to Forest. Generally, however, mapping is used in a sampling mode where soils, hydrology, timber, and other vegetation information are collected.

After mapping is complete, map units are stratified based on similar characteristics. For timber inventories, no distinction is made in the stratification process between forested wetlands and forested drylands (assuming that is the proper antonym).

Sampling units are drawn for field observation. The purpose of the field survey is to verify the mapping and to collect data that cannot be extracted from remote sensing or other sources. In timber, we would measure such things as tree heights, diameters, etc. to get estimates of resource condition and value. Data for other resource needs would be collected by other resource specialists.

Forest Inventory and Analysis inventories

Seven Forest Inventory and Analysis (FIA) Work Units have the responsibility of inventorying and monitoring the resources on all additional forested lands in the United States. This amounts to about 244 million ha (603

[1]One, Waterfowl Way, Long Grove, IL 60047; a non-profit, non-political corporation organized to perpetuate waterfowl and other wildlife in North America.

million acres). Of these, approximately 18.7 million ha (46.2 million acres) are classed as forested wetlands in the conterminous United States.

FIA conducts forest surveys on a state-by-state basis. The FIA units do not map the resources. Instead, a grid of plots is extended across the survey unit. Aerial photographs of plot locations are interpreted as being forest or non-forest (plus some other characteristics). A subsample of the photo plots are selected as field plots for gathering ground measurements.

FIA units do not distinguish between forested wetlands and other forest lands when classifying the photo plots or in stratifying the samples. Thus, estimates of forested wetland areas on the lands the FIA surveys must come from other sources or from assumptions based on forest type or other physical characteristics that are measured on the ground plots.

The FIA units do measure the resources on forested wetlands. The techniques employed and data collected are similar to NFS plots. Timber and other vegetation information is collected.

The Southern and Southeastern FIA units inventory the forest year round, while the North Central FIA unit inventories wetlands or swamps in the winter when the ground is frozen (J.S. Spencer, personal communication, 1988). The season of data collection is particularly important for lesser vegetation.

The Pacific Northwest FIA unit classifies forested westlands as 'other forest' in lieu of a class of 'timberland' if the land fails the test of being able to produce continuous crops of industrial-quality wood. As such, the unit may collect very limited data (D.R. Gedney, personal communication, 1988).

EBB TIDES

The need for more specificity and more cost–effective ways of doing business is causing some of our old ways of conducting inventories to change.

More specificity

The public is acutely interested in what is happening to the environment and in particular the National Forests. Special-interest groups have recently become concerned about the nation's dwindling old-growth and unroaded areas. Forested wetlands will surely join the list of environmental battlegrounds in the near future.

Neither NFS nor the FIA units identify or track resources on forested wetlands as such. If we are to furnish the necessary resource information, this must change. Special land classifications and related restrictions on land uses are certainly going to have a major impact on resource management in the future. Both Federal statutes and local regulations govern management and use of privately-owned land. State, county, town and other political entities

are implementing restrictions on resource use as well (J. Peters, personal communication, 1988).

As competition for limited resources increases, better information and more effective data-collection techniques will be necessary to give the resource decision maker the credibility he or she needs as competing interest groups scrutinize government decision-making. NFS has made some progress in its mapping program and the FIA units are now also looking at ways of producing theme maps to supplement their published reports. All of our field units will be gathering more complete information about ecosystems as a whole, including spatial and temporal information about soils, vegetation, water, fauna, and air. This data will allow us to make appropriate prescriptions that maintain the character and value of our forested wetlands.

Cost–effective methods

With the continuing pressures to reduce operating costs in the Forest Service, we must seek new opportunities for coordinating our inventories and making use of new technologies.

Information gathered from coordinated inventories and using new technologies will be entered into common data-banks containing basic vegetation, soil, and climate information to permit the rapid sharing of research and management experiences. Future research will make possible the increased use of forest and rangeland vegetation, including the development of new agricultural, chemical, and genetically-engineered products. New analytical models using soil and climatic data will be developed to predict yields of these emerging products.

FLASH FLOODS

Some changes are coming on quite rapidly.

Information requirements and integrated inventories

Recently the agency procured a Data General (DG)computer system to increase communications and to share information between field units. We now have about 900 computer systems installed and about 19 000 terminals. All the systems are connected by the DG network, making it the largest integrated network in the world. We can access our personal files from any of the computer systems and create and send messages, documents or files to any other user on any system.

We are also in the process of acquiring a geographic information system (GIS) for the entire Forest Service (Anonymous, 1988), which will supplement the DG network. As we move in the acquisition and implementation, it

will be essential that we have compatible data that are collected using like standards and that are similarly structured to feed the system.

The Forest Service is currently evaluating its information requirements. New direction is being developed in the form of a Forest Service Resource Inventory Handbook (Lund, 1987a). Within this directive, we will specify the inventory-derived information needed for future Forest planning, State surveys, the Resources Planning Act Assessments, and international needs. Supplementing that handbook will be a Resource Inventory Glossary. This glossary will contain the definitions, standards, and coding for about 300 variables measured or observed during the course of our inventories. This glossary will be available on our computer system so that field units can easily access it.

At the same time, NFS is switching from single purpose inventories to coordinated or integrated resource inventories to meet local, regional, national, and international needs (Lund, 1986). Since 1976, the FIA units have implemented multi-resource inventory methods.

New technology

In the past I have used the 'Star Trek' analogy regarding emerging technology (Lund, 1983, 1987b). I like to use the 'Enterprise' and its capabilities as an example of what our inventory and monitoring potential could be in the future.

Resource inventory, planning, and monitoring capabilities will grow rapidly as remote sensing, computer technology, and field techniques continue to mushroom. In fact, I believe our capabilities will exceed those of the Star Trek crew in the very near future.

For instance, instead of having to operate from a Starship, we will inventory and monitor a good portion of our resources right from our desks (or work stations). At the district or laboratory level, we could have real-time or near-real-time access to satellite imagery. Using the satellite imagery coupled with ancillary information in a Geographic Information System (GIS), we could identify or model possible wetland sites if they were not directly interpretable from remote sensing (wetlands generally occur in flat or depressed areas). Using digital terrain and climatic data, we could model areas that are likely to be classed as wetlands.

In the near future, we will be able to use vertical images from different sources to produce digital terrain models and 3-D mapping. Using this information plus that information available from remote sensing, we could have the capability of 3-D viewing of any area on a forest to see what the current wetland situation is. We could also use the GIS and existing data to analyze the 'what if?' type of questions to assist in local, regional, and national planning. By archiving remote sensing and comparing it with current imagery, we

could have the ability to periodically and perhaps automatically monitor changes in the resource base.

Of course, not all information will be available from remote sensing and computers. Like the Star Trek crews, we will have to go to the field to validate our estimates and analyses.

Highly effective sampling and estimating schemes that make use of prior information, such as importance and model-based sampling (Schreuder and Wood, 1986; Gregoire et al., 1987) and Bayes methods (Green, 1987), will be used to keep data collection to a minimum. As we enter the field, once again remote sensing and computer devices will come to our aid. Global Positioning Systems (GPS), which calculate one's geographic location based on readings from earth-orbiting satellites (Greer, 1987) and GPS-like devices could help us navigate to field locations and make some position measurements. Interactive portable data recorders, telephones, radios, and other communication devices will help transmit data from the field to unit headquarters and back again.

Video cameras, lasers, and thermal-sensing instruments could help us in our field measurements, such as in measuring the height of trees and determining their vigor. Eventually, through the use of robotics and sensing computers, machines may become available which could eliminate the need for humans going to the field.

Once data are obtained and stored in a database, they would be extrapolated back to the entire survey unit using available remote-sensing classification so that 'wall-to-wall' geographical and attribute databases are available. Modeling and accounting procedures will allow us new ways of keeping our inventories current. In fact, there may be such a reliance on modeling and accounting procedures, that resource inventories and mapping could become a thing of the past.

Given this new technology, our National Forests will have estimates of all resources for each and every hectare under their jurisdiction. In the future, our FIA units could have a daily national inventory and monitoring program of all forested lands (including forested wetlands) in the United States conducted primarily from the office and using satellite imagery and light field samples if so desired. In all probability, the FIA units will also be producing theme maps to accompany spell survey reports.

WHIRLPOOLS

These changes in information requirements and needs and rapid advances in technology are creating waves of opportunities for us in the Forest Service, that could also inundate us. Many of our field units are now caught in whirlpools of indecision as old methods ebb away and new methods pour in.

Information requirements and standards

Because the agency is very decentralized, any move towards standardization usually affects some field units. When the Resource Inventory Handbook and Glossary are issued, we can expect resistance by the field. The resistance to change is in direct proportion to the degree that field units are affected.

Multiple-resource inventories

Functional areas of responsibilities are hard to give up. Multi-resource inventories, although they have been conducted for some time by the FIA units (McClure et al., 1979), have not withstood the rigors of time and testing on NFS lands. Timing and intensity of surveys are the major areas in question when trying to develop inventories to satisfy multiple needs.

Technology effects

The new trend towards integrated inventories and new technology will greatly increase the quality of the data and add important new pieces of information that we will have to work with. These changes will in turn bring on their own whirlpool of problems. For example, the publication of maps showing where forested wetlands are may not be desirable. Such maps may conflict with other federal agencies' areas of responsibility, and may also attract people to such areas, thus causing more 'people' problems.

There is a problem of new technology not meshing with needs, and vice versa. We will find that, if we really want to implement some of the emerging technology, we will have to change some of our concepts and ways of doing business. For example, in all probability, we will not be able to use satellite imagery in the near future to produce the same kind of stand maps that we are now accustomed to using. We can, however, produce maps using spectral and ancillary data that show similar kinds of information, but the maps will not be the same. If we want to use satellite imagery, then we need to start thinking more in terms of spectral reflectance and location on the landscape rather than in canopy cover and forest type.

Deciding when to map wetlands, and the technology to be used, could present problems. If remote sensing is the primary source of information, identification of wetlands could be influenced by the effect of seasons and the use of treatments. This year, for example, would be a good one to create a base using remote sensing for those in the U.S.A. who wish to show increases in wetlands (assuming future years will be wetter). This year would also be a good monitoring year for use by crisis groups to illustrate decreases of wetlands. This points out the need for always including some ground-truth along with the use of new technologies.

Lastly, the private sector can and will use the same technology to see how well we are managing our resources. That means we all will have to be prepared for increased public scrutiny as we manage our resources in sensitive areas such as the forested wetlands.

GLOBAL ACTIONS NEEDED

In the past few pages I have covered how the USDA Forest Service inventories the resources on forested wetlands. I have reviewed some changes that are taking place, and touched upon some of the problems that may surface as a result of those changes. Papers that follow will provide additional insight to the opportunities and problems of others.

Several papers in this conference address the loss of forested wetlands. Fortunately, because of our federal laws and policies, little or no loss is occurring to our National Forests. Even so, Frayer (1987) estimates that the United States will lose about 800 000 ha (2 million acres) of forested wetlands between 1986 and 2000, primarily from the private sector.

The continued disregard for the preservation of forested wetlands on all lands needs to be changed. If it is not, the task of locating and identifying forested wetlands will become more difficult, while the inventory and monitoring of the resources will certainly become easier: there just won't be any wetlands left to inventory.

If we want the global destruction of our forested wetlands halted, there are four courses that we should consider.

(1) *Take a holistic approach to resource inventories.* Environmentalists and conservationists like to draw attention to lands that once were wetlands. For example, many organizations fighting to add areas to the U.S. Wilderness System cite how many hectares have been removed from wilderness potential, not how much area still remains.

Developers, on the other hand, prefer to focus on lands that aren't managed for exploitation, but could be. They focus on lands that have been set aside for other uses.

Lastly, resource managers look primarily at lands that are and, it is hoped, still will be maintained for current use. Thus resource managers focus on the areas that they are managing now. By doing so, they may not be able to answer the needs of the special-interest groups and may overlook opportunities to keep or expand the base available for resource management.

Therefore, we all need to be taking a more holistic view in our inventories. This will help ensure that special areas such as the forested wetlands are not overlooked, and provide a means for coordinating data collection and sharing. Emerging technology, particularly in the form of digital satellite remote sensing coupled with ground sampling, will help us take the holistic view. In

fact, it may be easier to inventory all lands and resources, rather than trying to single-out a specific feature of the lands to inventory.

(2) *Develop an international definition and classification system for wetlands.* The worldwide distribution and extent of the forested wetlands must be determined, along with standard terminology and definitions. If we want to address the forested wetlands on an international basis, and if we want others to understand our concerns, we need common means of identifying and classifying these areas. While we have a classification system (Cowardin et al., 1979) for the United States that provides some guidance, no such classification system exists on a global basis.

If a classification system were devised, it would have to incorporate technology that would be available on a global basis. This generally means satellite imagery. Again, we may need to bend our existing definitions to take advantage of the capabilities of emerging technology. This does not sit well with many groups who are trying to monitor change, but it is a reality if we do wish to do things internationally.

(3) *Have an international group champion the monitoring of forested wetlands on a global basis.* The International Union of Forestry Research Organizations (IUFRO) will most certainly support any recommendations that come from this conference, but that will not be enough. If we want international action, we need to have an international coordinating body which would develop standards and definitions, and which should have a role in reporting and monitoring resulting statistics. The Food and Agriculture Organization (FAO) of the United Nations may be a likely organization to approach. The FAO, in cooperation with the European Economic Community (EEC), produces periodic assessments of the forest resources of the world (Anonymous, 1985) and may be willing to include forested wetlands as a more-detailed breakdown.

(4) For my final point, I am going to use a take-off of a story told by comedian Jerry Clower (1984), of Yazoo City, Mississippi.

The 'hero' of the story scarcely listened as the weather forecasters broadcasted emergency flood-warnings to the local community. "God's gonna take care of me" the man thought to himself.

The floods began to arrive. A civil defense boat went up and down the flooded valley urging people to evacuate their houses. They stopped at the man's house, to which the flood waters had already reached up to the front porch. "Get in the boat and we'll take you to higher land", the boatman urged. "But I'm not going ", replied the man. "The Lord will save me!"

A little while later another boat passed the house. This time the waters were up to the gutters where the same man was desperately clinging. "Get in our

boat!" the rescuers pleaded. "Don't worry, God's gonna take care of me", the man cried.

The waters closed over the roof. The man stood atop the chimney. A helicopter hovered overhead. "Grab ahold of the rope and we will carry you to safety", begged the pilot over a bullhorn. "Go away, God will save me!" the man yelled once again.

BLAM! The next scene, the man is standing before God in heaven. "God, what happened? I trusted in you. You let me down! You embarrassed me!" cried the man. "You dummy!" exclaimed God. "I sent you a radio warning, two boats, and a helicopter. What more did you want me to do!"

We have been given repeated warnings about the decline of our environment. The tools to change that condition are at hand as evidenced by the papers presented at this conference. It is up to each and every one of us to heed those warnings and to grab hold and use the tools available to make this world a better place to live. *We cannot wait to rely on others to do this for us. We, as individuals, have to initiate the action ourselves and do it now.*

ACKNOWLEDGEMENTS

My thanks to the following Forest Service employees for their kind reviews and valuable suggestions: Ray Allison, Remote Sensing Coordinator; Jim Bones, Forest Inventory and Analysis Branch Chief; Pete Avers, Soil Resource Program Manager, Watershed and Air Management Staff; and Karl P. Siderits, Wildlife Program Manager, Wildlife and Fisheries Staff.

REFERENCES

Abercrombie, T.J. and Raymer, S., 1988. The Persian Gulf – living in harm's way. Nat. Geogr., 173: 648–671.

Anonymous, 1985. Forest resources 1980. Food and Agriculture Organization of the United Nations, Rome, 18 pp.

Anonymous, 1988. National GIS plan – Geographic information. USDA Forest Service, Information Systems, Washington DC, 14 pp.

Clower, J., 1984. God's gonna take care of me. In: Starke Raving. MCA Recording MCAC 952, MCA Records Universal City, CA.

Cowardin, L.M., Carter, V., Golet, F.C. and LaRoe, E.T., 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31, U.S. Dept. of the Interior, Fish and Wildlife Service, Washington, DC., 131 pp.

Frayer, W.E., 1987. In the absence of concern: Wetland projections to the year 2000. In: H.G. Lund, M. Caballero-Deloya and R. Villarreal-Canton (Editors), Land and Resource Evaluation for National Planning in the Tropics: Proceedings of the International Conference and Workshop; 25–31 January 1987, at Chetumal, Mexico. USDA, For. Serv., Gen. Tech. Rep. WO-39, pp. 383–385.

Green, E.J., 1987. Empirical Bayes procedures for updating forest inventories. In: Forests, the World, and the Profession: Proc. Soc. American Foresters National Convention, 5–8 October, 1986 at Birmingham, AL. Society of American Foresters, Bethesda, MD, SAF Publ. 87.02, pp. 67–69.

Greer, J.D., 1987. Global positioning systems technology: a field demonstration on the Apache-Sitgreaves National Forest in Arizona for non-cadastral uses. USDA Forest Service, Engineering Staff; Washington, DC, EM-7140-16, 36 pp.

Gregoire, T.G., Valentine, H.T. and Furnival, G.M., 1987. Importance sampling in forest inventory. In: Forests, the World, and the Profession: Proc. Soc. American Foresters National Convention, 5–8 October 1986, at Birmingham, AL. Bethesda, MD, SAF Publ. 87.02, Society of American Foresters, pp 70–73.

LaBau, V.J. and Kerr, C.L. (Editors), 1984. Proc. Int. Conf. on Inventorying Forest and Other Vegetation of High Latitude and High Altitude Regions, 23–26 July 1984 at Fairbanks, AK. Society of American Foresters, Bethesda, MD, SAF Publ. 84-11, 296 pp.

Lund, H.G., 1983. Star trek: a no-holds-barred journey into the future. In: J.F. Bell and T. Atterbury, (Editors), Proc. Renewable Resource Inventories for Monitoring Changes and Trends. 15–19 August 1983, at Corvallis, OR. Oregon State University, Corvallis, OR, SAF Publ. 83-14, 682–685 pp.

Lund, H.G., 1986. A primer on integrating resource inventories. USDA For. Serv., Washington, DC, Gen. Tech. Rep. WO-49, 64 pp

Lund, H.G., 1987a. Developing resource inventory policies for national land and resource evaluation and planning: In: H.G. Lund, M. Caballero-Deloya, and R. Villarreal-Canton (Editors), Land and Resource Evaluation for National Planning in the Tropics: Pro. Int. Conference and Workshop; 25–31 January 1987 at Chetumal, Mexico. USDA For. Serv. Gen. Tech. Rep. WO-39, Washington, DC, pp. 491–498.

Lund, H.G., 1987b. Star trek II: resource inventories of the future: In: Forests, the World, and the Profession: Proc. Soc. American Foresters National Convention; 5–8 October, 1986 at Birmingham, AL. Society of American Foresters, Bethesda, MD, SAF Publ. 87.02, pp. 311–315.

Lund, H.G., Caballero, M., Hamre, R.H., Driscoll, R.S. and Bonnor (Technical coordinators), 1981. Arid Land Resource Inventories: Developing Cost Effective Methods: Proceedings of an International Workshop; 30 November–6 December, 1980, at La Paz, Mexico.USDA For. Serv., Washington, DC, Gen. Tech. Rep. WO-28, 620 pp.

Lund, H.G., Caballero-Deloya, M. and Villarreal-Canton, R. (Editors), 1987. Land and Resource Evaluation for National Planning in the Tropics: Proceedings of the International Conferernce and Workshop; January 25–31, 1987 at Chetumal, Mexico. USDA For. Serv. Washington, DC, Gen. Tech. Rep. WO-39, 524 pp.

McClure, J.P., Cost, N.D., Knight, H.A., 1979. Multiresource inventories – a new concept for forest survey. USDA For. Serv., Southeast. For. Exp. Stn., Asheville, NC, Res. Pap. SE-191, 68 pp.

McLaughlin, K.R., 1988. Wetland management. Paper presented at the USDA Forest Service R-8 Soil and Water Management Workshop; 22–26 February 1988 at Tallahassee, FL, 17 pp.

Schreuder, H.T. and Wood, G.B., 1986. The choice between design-dependent and model-dependent sampling. Can. J. For. Res., 16:260–265.